

## **Estimating GHG Reductions From State Actions to Improve Solid Waste Management Practices**

This appendix contains three sections: (1) Background, (2) A Life Cycle Approach: Evaluating and Incorporating Solid Waste Management Actions in a Statewide GHG Mitigation Plan, and (3) Example Plan for Waste Management Mitigation Actions. The background section sketches some national trends in solid waste management actions, identifies solid waste management actions which may yield GHG reductions, and discusses the importance of integrating solid waste management actions into a statewide GHG mitigation action plan. The next section discusses the importance of using a life cycle approach for evaluating the GHG impacts of current and future solid waste management actions. In the last section of this appendix, an example MSW management scenario is presented for a hypothetical state looking to evaluate its current and future solid waste management actions from a GHG perspective. The example establishes a baseline scenario of solid waste management actions and compares it to a future scenario; the future scenario uses solid waste management as part a statewide GHG mitigation action plan.

### **Background**

To achieve statewide source reduction and recycling goals, many states and municipalities develop municipal solid waste (MSW) management plans which include a variety of measures such as curbside collection and recycling programs, recycling drop-off centers, and yard trimmings composting facilities. According to a recent nationwide survey, 45 states have waste reduction and/or recycling goals in place.<sup>1</sup> Nationwide, approximately 51% of the US population has access to curbside recycling, and the number of drop-off recycling programs continues to grow.<sup>2</sup>

Additional MSW management measures provide opportunities for states to meet and exceed their source reduction and recycling goals. Such measures include introducing “Pay As You Throw” (PAYT) pricing for waste collection, increasing the service area or improving collection efficiency of curbside recycling programs, increasing commercial sector recycling, and banning landfilling of organic wastes such as yard trimmings. Note that in most states, the role of state government is to develop plans and standards; local governments implement solid waste policy. Thus, any state actions addressing solid waste should start with full coordination and consultation with local officials.

Many states are in the process of reevaluating their MSW management goals. This reevaluation process provides the opportunity for state and local authorities to consider the GHG reduction benefits of different MSW management strategies currently in place, and identify opportunities to further achieve GHG reductions in the MSW sector. Viewing MSW management actions from a GHG perspective provides the basis for including and integrating these management actions into a statewide GHG mitigation action plan.

### **A Life Cycle Approach: Evaluating and Incorporating MSW Management Actions in a Statewide GHG Mitigation Plan**

To incorporate MSW management actions into a statewide GHG mitigation action plan, one must first identify the impacts of MSW management actions on GHG emissions. Heretofore, most of the focus on GHG emissions associated with waste management has been on methane emissions from landfills.

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<sup>1</sup> BioCycle, *The state of garbage in America*, April, 1997.

<sup>2</sup> Ibid.

There are, however, many emissions and sinks upstream of the point of disposal that are affected by MSW management. A life cycle approach provides an analytic framework for evaluating the full range of GHG emissions and sinks. Major GHG sources associated with MSW include carbon dioxide from fossil fuel burning associated with raw material extraction manufacturing processes, and transportation; process non-energy emissions; landfill methane; and waste combustion. These emissions are offset to some degree by energy recovery at municipal waste combustors and landfill gas collection systems, and enhanced carbon sequestration by forests and landfills.

For MSW management, EPA has conducted a streamlined life cycle inventory (LCI) focusing on the GHG impacts of ten MSW components (e.g., paper, plastics, metals) in various ways. The EPA draft working paper *Greenhouse Gas Emissions from Municipal and Solid Waste Management*<sup>3</sup> and the EPA's Waste Reduction Model (WARM)<sup>4</sup> provide GHG emission factors, for waste stream components, that are based on an LCI framework. EPA's research indicates that for many materials, the effect of recycling or source reduction on net GHG emissions is more closely related to upstream energy emissions and forest carbon sinks than to landfill methane emissions, and so a life cycle approach is able to capture the benefits of solid waste management options in a more holistic way.

EPA recognizes that LCIs have limitations. Data vary with respect to quality, quantity, validity, and robustness. For example, data may vary seasonally, regionally, and locally as a result of changes in economic activity, demographics, different state and local waste regulations, or different waste accounting practices. When state or local data are not available, it is possible to use averaged national data. Application of averaged national data may not accurately reflect state or local conditions. However, in the absence of state or local data, averaged national data are a good proxy. The EPA research to date, has very wide error bounds and is based on average national conditions; nevertheless, the information it provides on GHG emissions from waste management is suitable for estimating the impacts of voluntary GHG reduction activities.

### **Example Plan for Waste Management Mitigation Actions**

The objective of this example is to demonstrate to developers of State Action Plans the value of incorporating waste management activities in their plans. This example uses averaged national data to estimate GHG emissions resulting from the baseline and future MSW management scenarios for a hypothetical state. The initial (baseline) scenario is based on some simple assumptions about MSW management activities in the current year. This baseline scenario provides the starting point from which to consider future changes in MSW management actions. The future scenario is based on the successful implementation of a variety of waste management activities which result in increases in overall recovery and a reduction in GHG emissions.

The hypothetical scenarios focus on a set of ten materials<sup>5</sup> present in the MSW stream for which EPA has estimated GHG emission factors. EPA is conducting research to develop emission factors for additional materials such as glass and wood.

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<sup>3</sup> EPA 530-R-97-010. March 1997. USEPA Office of Solid Waste and Emergency Response.

<sup>4</sup> Available through the USEPA Office of Solid Waste.

<sup>5</sup> These materials include paper (office paper, newsprint, corrugated cardboard), metals (aluminum cans, steel cans), plastics (HDPE, LDPE, and PET), food scraps, and yard trimmings.

## Methodological Approach and Assumptions

To establish a baseline and future scenario for the hypothetical state, the following assumptions were made.

### *Waste Generation:*

Total waste generation is the product of the per-capita waste generation rate and the state population. In both the baseline and future scenarios, this analysis assumes a state population of 5 million people and a per-capita waste generation rate of 4.3 pounds of waste/person/day.<sup>6</sup>

### *Baseline Scenario Assumptions:*

The baseline scenario assumes the state currently landfills most of its waste, and also uses waste-to-energy as a management option. Recycling actions include curbside recycling programs in major residential areas, some recycling collection centers, some yard waste composting facilities, and a limited industrial/commercial recycling program. These assumptions are based largely on *BioCycle's* "The State of Garbage In America" which reported the number and types of MSW management programs in place for each state (April, 1997).<sup>7</sup>

The baseline scenario assumes these programs reflect common MSW management actions at the state and local level within the US, and that these actions result in a recovery rate of 27 percent, a combustion rate of 15 percent and a landfill rate of 58 percent.<sup>8</sup> The baseline data are presented in Table 1.

The baseline scenario assumes 20 percent of the waste destined for landfills is managed in landfills with landfill gas (LFG) recovery systems, and that these systems have a LFG collection efficiency of 75 percent. In addition, the baseline scenario assumes an overall waste-to-energy (WTE) efficiency rate (i.e., electrical energy output divided by energy value of waste inputs) of 17 percent.

### *Future Scenario Assumptions:*

The future scenario assumes the state implements a set of MSW management activities designed to achieve a higher total recovery rate by the year 2005 in response to state solid waste recovery goals (see Exhibit 1). The future scenario assumes these MSW management activities result in a waste recovery rate of 50 percent, a combustion rate of 15 percent, and a landfill rate of 35 percent. The future scenario data are presented in Table 2.

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<sup>6</sup> Calculated based on an estimated total US population of 260 million and a total amount of waste generated as reported in *Characterization of MSW in the United States 1996 Update*, EPA530-R-97-015.

<sup>7</sup> *BioCycle* reported approximately 49 of 51 states have curbside recycling programs, 40 of 51 states have recycling drop-off sites, and 48 of 51 states have yard waste composting facilities (for reporting purposes the District of Columbia was counted as a state).

<sup>8</sup> The total and material specific generation, recovery, and disposal rates are comparable to the national average rates for 1995 reported in EPA's *Characterization of Municipal Solid Waste in the United States: 1996 Update*.

**Exhibit 1**  
**Example of Future Scenario MSW Management Goals and Activities**

<b>Future Goals</b>	<b>Future Activities</b>
Increase newspaper recovery rate to 67 percent.	Increase collection efficiency of curbside collection.
Increase office paper and corrugated cardboard recovery rates to 67 percent.	Expand the commercial collection of mixed paper and corrugated cardboard.
Increase yard trimmings recovery rate to 40 percent.	Promote the benefits of composting. Create yard waste drop-off centers in addition to offering seasonal curbside collection of yard waste. Ban yard waste from landfills.
Increase food waste diversion rate to 25 percent.	Expand the commercial and institutional collection of food waste discards.

Specifically, the future scenario assumes a statewide recovery rate of 67 percent for newspaper, office paper, and corrugated cardboard; 25 percent for food scraps; and a landfill ban on yard trimmings. The material-specific recovery rates for the remaining materials were adjusted upward to achieve a total recovery rate of 50 percent.

The future scenario assumes 60 percent of the waste destined for landfills is managed in landfills with landfill gas (LFG) recovery systems, and that these systems have a LFG collection efficiency of 85 percent. In addition, the future scenario assumes the overall waste-to-energy (WTE) efficiency rate improves to 19 percent.

In an actual state report, the future scenario for the total and material-specific recovery, combustion, and landfill rates would be based on the state's MSW management goals and activities.

*The Waste Reduction Model (WARM)*

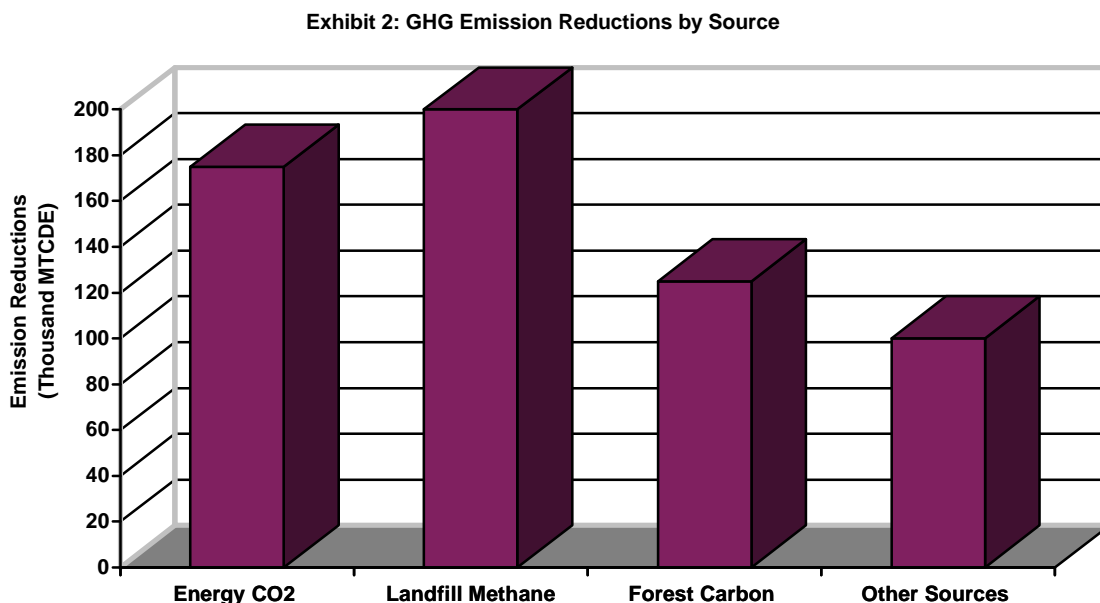
WARM, an EPA software model for estimating GHG emissions from the waste management sector, was used to estimate GHG emissions for this analysis. Table 3 presents the GHG emission estimates for the baseline scenario, and Table 4 presents the GHG emissions for the future scenario. Table 5 compares the estimates from the two scenarios.

**Results of Example Analysis and Relationship to Other Mitigation Activities**

WARM estimates of annual GHG emissions in the baseline and future scenarios are summarized in columns "b", "c", and "d" of Table 5. The estimated GHG emissions are 1.5 million MTCDE per year in the baseline scenario and 930,000 MTCDE per year in the future scenario. The future scenario thus reduces emissions by about 600,000 MTCDE per year.

The largest reductions in GHG emissions were for office paper (224,000 MTCDE per year), corrugated boxes (153,000 MTCDE per year), newspaper (114,000 MTCDE per year), and food waste (103,000 MTCDE per year). Most of the reductions are attributable to reduced energy-related carbon

dioxide emissions, reduced landfill methane emissions, and increased forest carbon sequestration. (Exhibit 2)<sup>9</sup>



The estimated 600,000 MTCDE emission reduction predicted in this exercise is comparable in magnitude to some of the most significant tools available to states for reducing GHG emissions. For comparison, examples of policy and technology options that reduce GHG emissions by similar levels are found in several state action plans. One such option can be found in Illinois' action plan, which estimated that efficiency improvements to hot water heaters and residential furnaces have the potential to reduce GHG emissions by approximately 582,000 and 514,000 MTCDE, respectively, by the year 2000. In Oregon, improved natural gas efficiencies have the potential to reduce GHG emissions by approximately 655,000 MTCDE by the year 2010. Washington estimates that improved food refrigeration may reduce GHG emissions by approximately 500,000 MTCDE by the year 2010.

MSW management options thus represent significant opportunities for states to further reduce their GHG emissions. Because these options have other environmental benefits as well, they deserve careful consideration in Action Plans.

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<sup>9</sup> Potential exhibit comparing the "breakout" by source for the baseline and future scenarios.

Table 1  
Baseline Scenario for the Management of Municipal Solid Waste in the Current Year for a State "Mock-Up"

**Baseline Scenario Assumptions**

State's Population	Annual MSW Generation <sup>1</sup> (tons)	Percent of Total MSW Recovered	Percent of Total MSW Combusted	Percent of Total MSW Landfilled	Percent of Landfilled Waste Managed at Landfills with LFG Systems	Collection Efficiency of LFG Systems	Conversion Efficiency of Waste-to-Energy (WTE) Systems
5,000,000	4,015,000	27%	15%	58%	20%	75%	17%

**Generation and Management of MSW in Current Year**

(a)  Material	Current Waste Generation		Current Waste Recovery		(f)  Amount of Waste Discarded <sup>5</sup> (tons)	(g)  Amount of Waste Combusted (tons)	(h)  Amount of Waste Landfilled with no LFG System (tons)	(i)  Amount of Waste Landfilled with LFG System (tons)
	(b) Percentage of MSW Generation <sup>2</sup> (by weight)	(c) Amount of Waste Generated <sup>3</sup> (tons)	(d) Percentage of Waste Recovered <sup>4</sup> (by weight)	(e) Amount of Waste Recovered (tons)				
Newspaper	6.3%	252,945	53.0%	134,061	118,884	24,428	75,565	18,891
Office Paper	3.3%	132,495	44.3%	58,695	73,800	15,164	46,908	11,727
Corrugated Cardboard	13.8%	554,070	64.2%	355,713	198,357	40,758	126,079	31,520
Aluminum Cans	0.8%	32,120	62.7%	20,139	11,981	2,462	7,615	1,904
Steel Cans	1.3%	52,195	56.8%	29,647	22,548	4,633	14,332	3,583
HDPE	1.9%	76,285	10.8%	8,239	68,046	13,982	43,251	10,813
LDPE	2.7%	108,405	1.7%	1,843	106,562	21,896	67,733	16,933
PET	0.5%	20,075	22.7%	4,557	15,518	3,189	9,863	2,466
Food Scraps	6.7%	269,005	4.1%	11,029	257,976	53,009	163,974	40,993
Yard Trimmings	14.3%	574,145	30.3%	173,966	400,179	82,229	254,360	63,590
<b>SUBTOTAL</b>	51.6%	2,071,740	38.5%	797,889	1,273,851	261,750	809,681	202,420
Other Materials	48.4%	1,943,260	14.7%	286,161	1,657,099	340,500	1,053,279	263,320
<b>TOTAL</b>	100.0%	4,015,000	27.0%	1,084,050	2,930,950	602,250	1,862,960	465,740

<sup>1</sup> Assuming 5 million people generate 4.4 lbs of waste/person/day.

<sup>2</sup> Franklin Associates, Ltd. *Characterization of Municipal Solid Waste in the United States: 1996 Update*, EPA 530-R-97-015.

<sup>3</sup> The product of total MSW generation and percent of MSW generation for each material. For example, 4,015,000 tons/yr x 0.063 = 252,945 tons/yr of newspaper.

<sup>4</sup> Percentage recovery for each material based on national average from Franklin Associates, Ltd., EPA 530-R-97-015. Yard waste recovery means back yard composting.

<sup>5</sup> The difference between the amount of waste generated and the amount of waste recovered.

Table 2  
Future Scenario for the Management of Municipal Solid Waste by Year 2005 for a State "Mock-Up": Assuming Increased Material Recovery

**Future Scenario Assumptions**

State's Population	Annual MSW Generation <sup>1</sup> (tons)	Percent of Total MSW Recovered	Percent of Total MSW Combusted	Percent of Total MSW Landfilled	Percent of Landfilled Waste Managed at Landfills with LFG Systems	Collection Efficiency of LFG Systems	Conversion Efficiency of Waste-to-Energy (WTE) Systems
5,000,000	4,015,000	50%	15%	35%	60%	85%	19%

**Generation and Management of MSW in Year 2005**

(a)  Material	Future Waste Generation		Future Waste Recovery		(f)  Amount of Waste Discarded <sup>5</sup> (tons)	(g)  Amount of Waste Combusted (tons)	(h)  Amount of Waste Landfilled with no LFG System (tons)	(i)  Amount of Waste Landfilled with LFG System (tons)
	(b) Percentage of MSW Generation <sup>2</sup> (by weight)	(c) Amount of Waste Generated <sup>3</sup> (tons)	(d) Percentage of Waste Recovered <sup>4</sup> (by weight)	(e) Amount of Waste Recovered (tons)				
Newspaper	6.3%	252,945	67.0%	169,473	83,472	25,042	23,372	35,058
Office Paper	3.3%	132,495	67.0%	88,772	43,723	13,117	12,243	18,364
Corrugated Cardboard	13.8%	554,070	67.0%	371,227	182,843	54,853	51,196	76,794
Aluminum Cans	0.8%	32,120	65.0%	20,878	11,242	3,373	3,148	4,722
Steel Cans	1.3%	52,195	60.0%	31,317	20,878	6,263	5,846	8,769
HDPE	1.9%	76,285	15.0%	11,443	64,842	19,453	18,156	27,234
LDPE	2.7%	108,405	5.0%	5,420	102,985	30,895	28,836	43,254
PET	0.5%	20,075	25.0%	5,019	15,056	4,517	4,216	6,324
Food Scraps	6.7%	269,005	25.0%	67,251	201,754	60,526	56,491	84,737
Yard Trimmings	14.3%	574,145	40.0%	229,658	344,487	51,673	9,646	14,468
<b>SUBTOTAL</b>	51.6%	2,071,740	48.3%	1,000,458	1,071,282	321,385	299,959	449,939
Other Materials	48.4%	1,943,260	51.8%	1,007,042	936,218	280,865	262,141	393,211
<b>TOTAL</b>	100.0%	4,015,000	50.0%	2,007,500	2,007,500	602,250	562,100	843,150

<sup>1</sup> Assuming the state population of 5 million people and the waste generation rate of 4.4 lbs of waste/person/day have not changed by the year 2005.

<sup>2</sup> Franklin Associates, Ltd. *Characterization of Municipal Solid Waste in the United States: 1996 Update*, EPA 530-R-97-015.

<sup>3</sup> The product of total MSW generation and percent of MSW generation for each material. For example, 4,015,000 tons/yr x 0.063 = 252,945 tons/yr of newspaper.

<sup>4</sup> Assuming these are the recovery rate goals achieved by the year 2005. Yard waste recovered includes back yard and centralized composting.

<sup>5</sup> The difference between the amount of waste generated and the amount of waste recovered.

Table 3  
Estimated GHG Emissions from MSW Management Actions in the Baseline Scenario  
(Estimated Using WARM)

(a)	(b)	(c)	(d)	(e)	(f)			(g)	(h)	(i)	(j)	(k)
Material	Baseline Generation of Material (Tons)	Estimated Recycling (Tons)	Annual GHG Emissions from Recycling (MTCDE)	Estimated Landfilling (Tons)	Annual GHG Emissions from Landfilling (MTCDE)			Estimated Combustion (Tons)	Annual GHG Emissions from Combustion (MTCDE)	Estimated Composting (Tons)	Annual GHG Emissions from Composting (MTCDE)	Total Annual GHG Emissions (MTCDE)
					LFs without LFG recovery	LFs with LFG recovery	Total					
Newspaper	252,945	134,061	-185,829	94,456	107,922	11,639	119,561	24,428	33,254	0	0	-33,014
Office Paper	132,495	58,695	-52,950	58,635	280,253	25,656	305,908	15,164	26,154	0	0	279,113
Corrugated Box	554,070	355,713	-405,678	157,599	301,554	22,292	323,846	40,758	42,499	0	0	-39,334
Aluminum Cans	32,120	20,139	112,359	9,519	153,774	38,444	192,218	2,462	49,764	0	0	354,341
Steel Cans	52,195	29,647	59,380	17,915	59,866	14,967	74,833	4,633	19,416	0	0	153,629
HDPE	76,285	8,239	10,230	54,064	116,933	29,233	146,166	13,982	59,954	0	0	216,351
LDPE	108,405	1,843	2,705	84,666	230,652	57,663	288,315	21,896	109,256	0	0	400,275
PET	20,075	4,557	9,087	12,329	43,149	10,787	53,937	3,189	18,023	0	0	81,047
Food Waste	269,005	0	0	204,967	142,889	-7,334	135,555	53,009	-2,212	11,029	0	133,343
Yard Waste	574,145	0	0	317,950	22,122	-32,603	-10,480	82,229	-5,694	173,966	0	-16,175
<b>Total</b>	<b>2,071,740</b>	<b>612,894</b>	<b>-450,696</b>	<b>1,012,101</b>	<b>1,459,114</b>	<b>170,744</b>	<b>1,629,858</b>	<b>261,750</b>	<b>350,414</b>	<b>184,995</b>	<b>0</b>	<b>1,529,576</b>

Table 4  
Estimated GHG Emissions from MSW Management Actions in the Future Scenario  
(Estimated Using WARM)

(a)	(b)	(c)	(d)	(e)	(f)			(g)	(h)	(i)	(j)	(k)
Material	Baseline Generation of Material (Tons)	Projected Recycling (Tons)	Annual GHG Emissions from Recycling (MTCDE)	Projected Landfilling (Tons)	Annual GHG Emissions from Landfilling (MTCDE)			Projected Combustion (Tons)	Annual GHG Emissions from Combustion (MTCDE)	Projected Composting (Tons)	Annual GHG Emissions from Composting (MTCDE)	Total Annual GHG Emissions (MTCDE)
					Lfs without LFG recovery	Lfs with LFG recovery	Total					
Newspaper	252,945	169,473	-234,916	58,430	33,380	21,435	54,815	25,042	32919	0	0	-147,183
Office Paper	132,495	88,772	-80,082	30,606	73,143	39,770	112,913	13,117	22098	0	0	54,930
Corrugated Box	554,070	371,227	-423,372	127,990	122,450	53,558	176,008	54,853	54924	0	0	-192,439
Aluminum Cans	32,120	20,878	116,481	7,869	63,563	95,345	158,908	3,373	68182	0	0	343,571
Steel Cans	52,195	31,317	62,726	14,615	24,419	36,628	61,046	6,263	26255	0	0	150,027
HDPE	76,285	11,443	14,208	45,390	49,086	73,628	122,714	19,453	81274	0	0	218,196
LDPE	108,405	5,420	7,956	72,089	98,195	147,293	245,488	30,895	150763	0	0	404,207
PET	20,075	5,019	10,008	10,539	18,442	27,664	46,106	4,517	25273	0	0	81,387
Food Waste	269,005	0	0	141,228	49,227	-15,677	33,550	60,526	-3369	67,251	0	30,181
Yard Waste	574,145	0	0	24,114	839	-8,676	-7,837	51,673	-4429	498,358	0	-12,266
<b>Total</b>	<b>2,071,740</b>	<b>703,548</b>	<b>-526,991</b>	<b>532,871</b>	<b>532,744</b>	<b>470,968</b>	<b>1,003,711</b>	<b>269,712</b>	<b>453,890</b>	<b>565,609</b>	<b>0</b>	<b>930,610</b>

Table 5  
Comparison of Total Estimated GHG Emissions For the Baseline and Future Scenarios

(a)	(b)	(c)	(d)
	<b>Baseline Scenario: Estimated Total Annual GHG Emissions* (MTCDE)</b>	<b>Future Scenario: Estimated Total Annual GHG Emissions** (MTCDE)</b>	<b>Difference Between Baseline and Future Scenario Estimates of Annual GHG Emissions (MTCDE)</b>
<b>Material</b>			
Newspaper	-33,014	-147,183	-114,169
Office Paper	279,113	54,930	-224,183
Corrugated Boxes	-39,334	-192,439	-153,106
Aluminum Cans	354,341	343,571	-10,770
Steel Cans	153,629	150,027	-3,602
HDPE	216,351	218,196	1,846
LDPE	400,275	404,207	3,932
PET	81,047	81,387	340
Food Waste	133,343	30,181	-103,162
Yard Waste	-16,175	-12,266	3,909
<b>Total</b>	<b>1,529,576</b>	<b>930,610</b>	<b>-598,966</b>

\* These data were copied directly from Table 3, column k.

\*\* These data were copied directly from Table 4, column k.